Технічні науки

UDC 532.546.2

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STUDY OF HYDRODYNAMICS REGULARITIES IN CONTACT APPARATUS OF COUNTER-CURRENT TYPE

Summary. *The article examines the flow patterns in counter-current contact devices in a laminar mode. The characteristics of heat carriers that affect the stabilization of flow in devices, which largely determine the efficiency of counter-current devices, are studied.*

Key words: *counter-current contact devices, heat carrier, laminar mode, stabilization section, liquid film thickness.*

Introduction. The widespread use of counter-current devices is due to the fact that they have a number of advantages. These devices have high thermal efficiency due to the developed heat exchange surface and direct contact of the heat carriers. Due to the simplicity of the design and reduced metal consumption, they are characterized by relatively small capital costs for the manufacture of the contact device. The insignificant hydraulic resistance of the device and the ease of its use determine small operating costs. These devices are widely used in such industries as the petrochemical, chemical, food industry, energy, etc.

A large number of works are devoted to the study of transfer processes in contact devices [1-24]. Of particular interest is the study of the flow patterns in these devices. In this case, it is important to study the characteristics of flow stabilization, which largely determines the efficiency of contact devices.

The purpose of this work was to study the movement of gas flow and liquid film in contact devices of counter-current type in laminar mode. Particular attention was paid to determining the length of the hydrodynamic stabilization section in devices of this type.

To determine the length of the stabilization section, a set of computational experiments was carried out based on the proposed model. At the outlet of the channel, the pressure was set equal to atmospheric pressure, and at the inlet of the channel, the flow velocity values were set. To form developed flow velocity profiles, there are two pre-included sections in front of the coaxial channel: by air (h = 0...50 mm) and by liquid film (h = 1050...1000 mm).

The boundary conditions at the boundary of the flows and on the wall were determined by the adhesion condition. At the boundary of the flows, the condition of equality of friction forces was added. The influence of gravity on the flows was taken into account; the initial volume fraction of water in the air was taken equal to zero in all cases.

The studies were carried out in the following range of parameter changes at the channel inlet: water velocity is W_f = 0.12-0.6 m/s, water film thickness δ_f= 0.22-0.42 mm; in the laminar flow regime, the velocity is W_{air} = 0.3…1.5 m/s, which corresponds to Re_{air} = 420…2100. The height of the coaxial channel is H = 1.0 m; its diameters $d_1 = (2...34)10^{-3}$ m, $\Delta d = (20...34)10^{-2}$ m. During the modeling process, a wall step of 0.025 mm in air and 0.01 mm in a water film was selected, which is less than the thickness of the minimum boundary layer at a distance of 1 mm (water $1.2e^{-4}$ m and air $4.8e^{-4}$ m).

The obtained results of modeling are presented in Fig. 1, Fig. 2, Fig. 3. As follows from the data presented in Fig. 1 and Fig. 2, the main factors determining the length of the stabilization section in counter-current contact devices with laminar flow are the liquid film speed and its thickness. The geometric parameters of the channel and the air speed with laminar flow have virtually no effect on the length of this section (Fig. 2, Fig. 3).

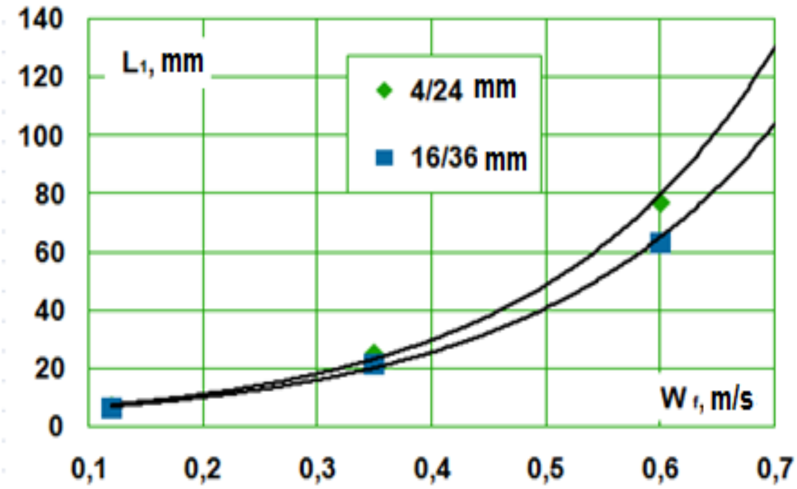

Fig. 1. Dependence of the length of the stabilization section on the film speed for different diameters of the coaxial channel. Air speed 0.85 m/s, corresponding to Re_{air} = 1200, *H*=1 m, film thickness 0,22…0,42 mm

In its final form, the equation describing the length of the hydrodynamic stabilization section in the film has the form

$$L_1/H = exp(43{,}868)(\delta/H)^{5{,}6}Re_f^{-0{,}57}.$$

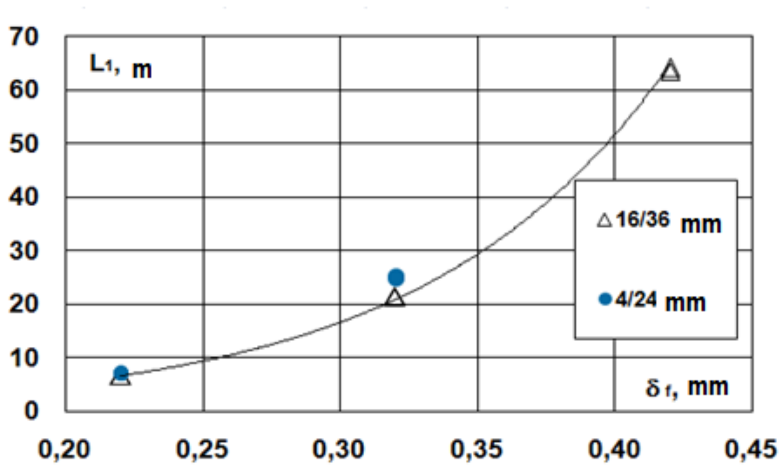

Fig. 2. Dependence of the length of the stabilization section on the film speed of 0.22...0.42 mm with changes in channel diameters. Air speed 0.3-1.5 m/s, corresponding to Re_{air} = 424-2120, H=1 m, water film speed 0.12-0.6 m/s

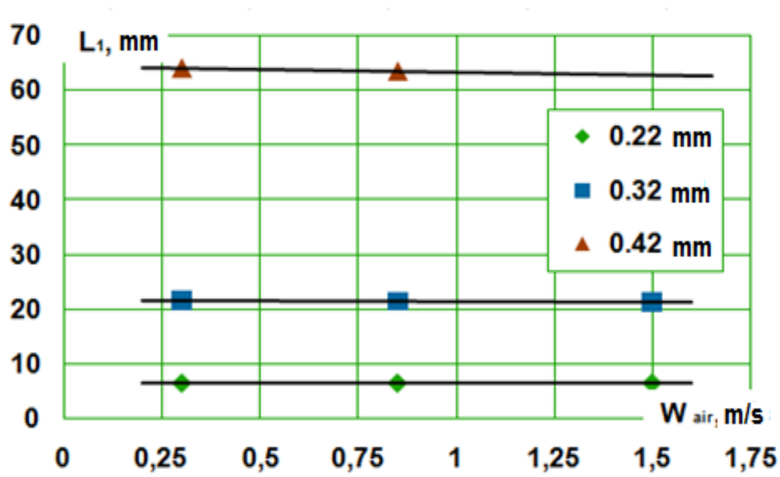

Fig. 3. Dependence of the length of the stabilization section on the air speed for different film thicknesses of 0.22…0.42 mm; channel height H=1 m, coaxial channel diameters 16/36 mm

The equation is obtained in the range $\delta/H = (2{,}2\ldots4{,}2)10^{-4}$, $\Delta\, d/H = (20\ldots34)10^{-3}$, $d_1/H = (2\ldots34)10^{-3}$, $Re_f = 20\ldots200$, $Re_{air} = 400\ldots2100$.

Conclusions. Based on CFD modeling, studies were performed to study the flow patterns in counter-current type contact devices under laminar modes of counter-movement of liquid and air films. It was investigated that the length of the section of hydrodynamic stabilization of the liquid film is determined mainly by the speed of the liquid film at the entrance to the coaxial channel, as well as the thickness of the liquid film. And it was found that the length is almost independent of the geometric characteristics of the channel and the parameters of the air flow. The results of mathematical modeling for the obtained criterial equation for determining the length of the section of hydrodynamic stabilization are also summarized.

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